Thompson, Walter Palmer

Heredity and education

compliments of the writer.

Thompson, Walter Palmer (1889-)

HEREDITY AND EDUCATION

Paper delivered by W. P. Thompson, Ph. D. at the Eighth Annual Convention of the Saskatchewan Educational Association at Prince Albert, April 24, 25, 26 and 27, 1916

HEREDITY AND EDUCATION

BY W. P. THOMPSON, PH. D.

The value of a manufactured article depends on two things, the quality of the raw material and the carefulness of the workmanship. The value of a human being to society depends on the same two things but in the human connection the raw material is called heredity and the workmanship is called training or education. In the meetings of this association we confine our attention almost exclusively to the second factor, the training. But in the present paper I intend to discuss the other, and in many respects more fundamental factor—Heredity.

The best of workmen can make but an inferior article when the raw material is poor. The poorest of workmen may make a serviceable article if the raw material is good. It is obvious, therefore, that the teacher—the workman—should be thoroughly familiar with the facts and laws and limitations of heredity, with its relative importance, and with the methods by which it may be improved.

The reason that heredity has played such a small part in educational theory and practice in the past is lack of knowledge concerning it. Until ten years ago there was great justification for Balzac's statement that heredity was a maze in which the scientist lost himself. But the scientist now has the string of Ariadne attached to his heel and may penetrate fearlessly anywhere in the labyrinth. The biologist's Ariadne is a fat Austrian monk (fig. 1) named Mendel, and his string is the law of heredity which he discovered. With its help we see that the maze is really very wonderfully, yet simply planned. The greatest advances in the science of biology in the present century have been made in the field of heredity. They not only go to the very fundamentals of biology and modify our ideas of evolution, our philosophy, our ethics, but also are of great practical importance, revolutionizing our practices in plant and animal breeding, and profoundly affecting sociological and uplift measures.

For our present purpose two great forward steps need to be explained. The first of these is the final solution of the interminable question of the inheritance of acquired characters. The question is this: can characters acquired during the lifetime of the individual be transmitted to its offspring? For example, will the improvement in mental capacity brought about by the teacher be passed on to the offspring of the student? Will the improvement in body wrought by the doctor, in morals by the preacher, in mind by the teacher, in body, mind and morals by the social uplifter, be a permanent inborn heritage of the race? Again, if the farmer by generous feeding increases the size of his cattle, will that increase be transmitted to the next generation? Unfortunately we must answer in the negative. Our reasons are twofold, the results of practical experiments and of theoretical deductions.

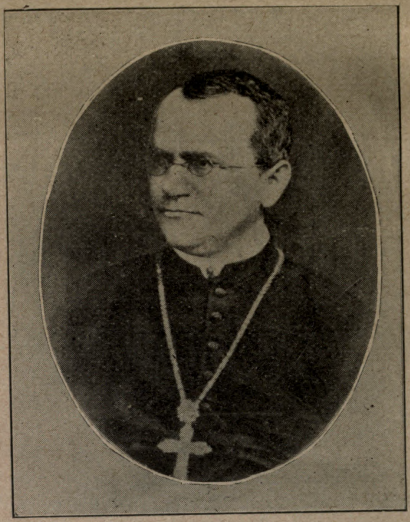

FIGURE 1
Gregor Mendel

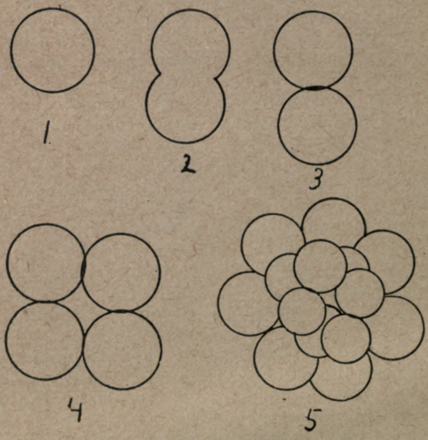

FIGURE 2

Early development of the animal body showing the division of the fertilized egg into two cells, then four, etc.

Innumerable special experiments might be cited, but many have been performed without a biologist's suggestion. Chinese women have compressed their feet for centuries, but, alas, must continue to do so to secure the desired smallness. Their white sisters have been no more successful. Savages' foreheads have been slanted, noses pierced, beards have been cut off, circumcision practised, immunity to measles acquired for endless generations, and the babies of the last generation are no more modified than those of the first. Remembering the commonness of wounds and mutilations we should thank our stars that this is true, or the human race would soon be in a very dilapidated condition. In short "wooden legs do not run in families, though wooden heads do."

But there are the best of theoretical grounds for the same conclusion. Our bodies develop from a single microscopic cell, the egg or female germ cell, through the division of the latter into two, then four, then eight, etc. (fig. 2). In this development a residue of unaltered germinal material is kept apart to form the germ cells of the next generation. The germ plasm is thus handed on from generation to generation (figure 3) and our bodies rise as side branches on that continuous stream. Therefore anything affecting the body of the father cannot affect the germ cell from which the boy develops. The hen does not produce the egg, but the egg produces the hen and other eggs in her body, and from those other eggs the next generation develops. "The boy is not a chip off the old block, but boy and father are chips off the same block." How can hypertrophy of the heart, caused by overwork, affect the reproductive cells so that the offspring will also have hypertrophy of the heart, seeing that germ cells have no heart? How can a mental change resulting in ability of solve quadratics affect the germ cells so that the child will find quadratics easy seeing that germ cells have no minds?

This internal inheritance must not be confused with external inheritance. We may receive money or a farm from our parents. In exactly the same way we may inherit accumulated stores of knowledge or our attitude towards knowledge. But our capacity for assimilating and using that knowledge is no greater than if it had never been stored. A father will educate his son because he himself was educated, but the mental capacity of the boy is no greater than if the father had remained untrained. It seems, therefore, that we teachers are denied one of the greatest rewards of our labor (and the rewards seem all too small to have any of them denied us), namely, the thought that we are each doing our bit toward the uplift of the inborn mental and moral qualities of the race.

The other big advance, which is of importance in the present connection, is really one of the great forward steps of science comparable to Darwin's Evolutionary hypothesis, or Pasteur's pioneer work on bacteria. To biologists it has become familiar as Mendel's Law of Heredity, and is in fact the Ariadne string to which we have referred. For the sake of the non-biologists I must explain it briefly. First, however, it should be remarked that the advance was really made fifty years ago, but at that time biologists were too busy fighting the theologians over Darwin's theory of evolution to grasp its significance. Consequently it lay buried and useless until the opening years of the present century—fifteen years after the death of its discoverer—when it was rediscovered simultaneously by three prominent botanists.

The law can be grasped most readily if we take a concrete example of its operation. For the practical work in my class in Heredity at the University of Saskatchewan we have fifteen distinct varieties of the ordinary fruit fly. Some have dark red eyes, some white eyes, some no eyes at all; some have yellow bodies; some grey, some black; some have long, fully-formed wings, some mere clubs or vestiges in place of wings. All these varieties have appeared spontaneously in our cultures within the last five years as sports of mutations. All the known laws of heredity can be illustrated properly planned experiments in crossing these varieties. My students have just finished working out for themselves from the results of these crosses the most fundamental laws of heredity.

When we cross a fly possessing the normal long wings with one possessing only the minute vestiges

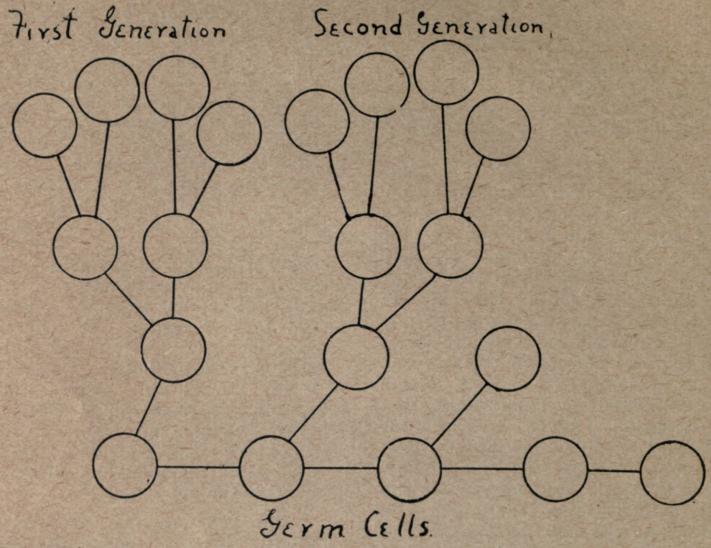

FIGURE 3

The germ cells of one generation give rise directly to those of the next thus forming a continuous stream of germ plasm (lower line) from which the body of each generation arises as a side branch.

or clubs (figure 4), the offspring are invariably all long winged. The vestigial character seems to have disappeared. But when these hybrid offspring are mated together a small and constant proportion of their offspring invariably have the vestigial wings exactly as in the grandparental generation. Out of every four individuals of the second hybrid generation one will have vestiges only and three will have the normal wings (figure 4). We say, therefore, that the vestigial character is hidden or recessive in the progeny of first cross, and that the normal wings are dominant. On further breeding (figure 5) we find that the one vestigial always breeds true, as does one of the three longs. while the remaining two longs give longs and vestigials in the same 3 to 1 ratio.

The explanation is simple. The two contrasting characters, long and vestigial wings, are inherited as units, never losing their identity, never blending nor becoming diluted though one is temporarily obscured by dominance. Further, the factor, whatever it may be, which represents the long wings in the reproductive cells never goes into the same reproductive cell as that which represents the vestigial character. If the father contributed the factor for long wings and the mother the factor for vestigial, these separate in the germ cells of the offspring so that half the germ cells contain the unit for long wings and half the unit for vestigial. The two assumptions then are the unit character inheritance and the segregation of these units into different germ cells. Now let us see how these assumptions explain our results (figure 6).

The hybrids will contain the units for both characters, the vestigial in a recessive condition (in brackets in figure 6). According to our assumption when the reproductive cells of these hybrids are formed they will be of two kinds, one containing the unit for long, one that for vestigial. Both male and female hybrids will have both types of germ cells. Any male germ cell may fertilize any female germ cell (as indicated by the arrows). There will thus be 1 LL, 2 LV, and 1 VV. The 1 VV. is our single vestigial one which breeds true; the 1 LL. is the single long, which breeds true; the 2 LV. are our two longs, which continue to throw vestigials as their parents did. Thus our assumptions are borne out by the actual breeding result.

There are then two general ideas in Mendel's Law of Heredity, the idea of unit characters, and the idea of segregation or purity of germ cells. We must consider our bodies as a bundle, as a mosaic of units which are inherited independently, though perhaps temporarily obscured by dominance. Further any one germ cell is able to carry only one of a pair of contrasting characters. It may carry a factor for blue eyes or one for black eyes, but not both. It must be pure for one or the other of such a pair. This purity of the germ cells is the most essential part of the law. It explains not only the segregation of dominant and recessive characters from a hybrid in which both are present, but also the relative numbers of pure dominants, pure recessives and mixed dominant-recessives.

Since Mendel's time innumerable characters have been investigated both in plants and animals, and in every case the inheritance has been shown to follow Mendel's Law. Such characters are the height of plants, colors of flowers, size of seeds, presence of beards, color of fur, length of hair, broodiness in chickens, pacing gait of horses, etc. At first it was supposed that Mendelism was an isolated type of inheritance, characteristic of a few cases only, but now we know that its application is universal. In human beings it controls the inheritance of all kinds of characters; bodily characters such as shape of head or nose, color of eyes or hair; physiological characters such as immunity to disease, digestive powers, or keenness of sight. We shall see in a moment that it is equally applicable to mental and moral qualities. For the present we must enquire why Mendel's Law holds.

Mendel knew of no mechanism by which his law could be explained. But microscopic examination of the reproductive cells have shown us that the characters could not behave in any other way. This is a brilliant piece of work with which all biologists should be familiar. The male reproductive cell or sperm of every species of animal and plant and of human beings carries a definite number of rod-like bodies called chromosomes (figure 8). (1) Each of these rods is different from every other in size and shape and constitution, and is in fact a per-

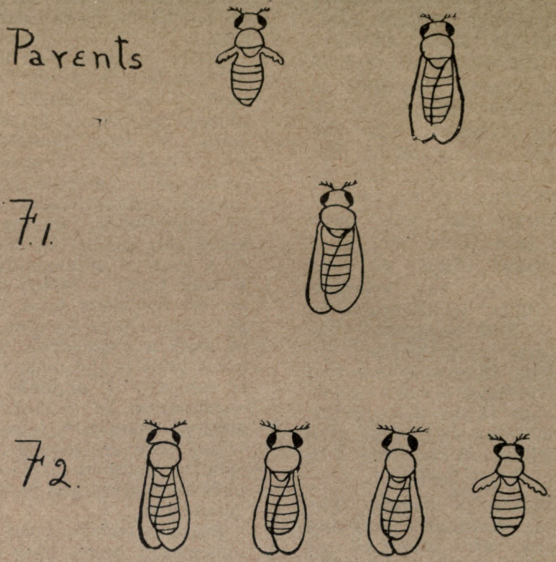

FIGURE 4

A cross between a normal long-winged fruit fly and a vestigial (club) winged. (F. 1) first hybrid generation, all flies alike and long winged. (F. 2) second hybrid generation has longs and vestigials in proportion of 3 to 1.

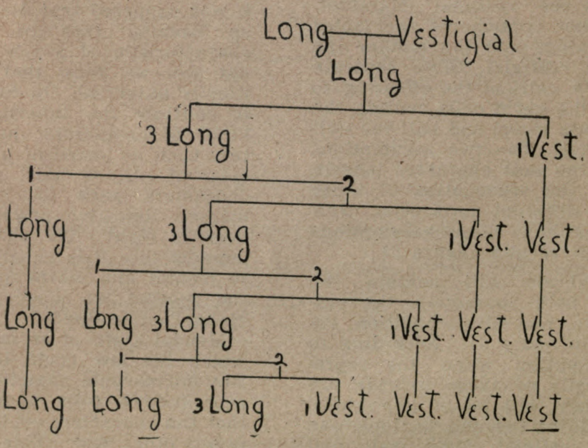

FIGURE 5

Results of continued breeding of the cross shown in figure 4. The one vestigial of the second generation breeds true; of the three longs 1 breeds true while the other two give rise to longs and vestigials in the same proportion as did the first generation hybrids.

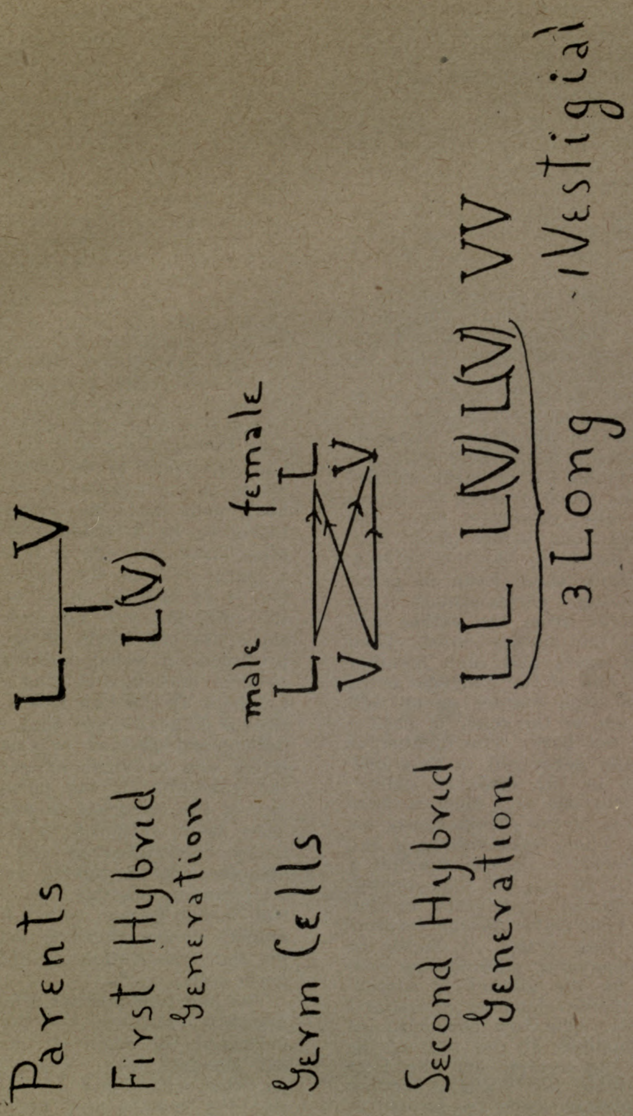

FIGURE 6

Explanation of Mendel's Law. See text.

manent organ of the cell. Every female reproductive cell or egg has an exactly similar set of rods (figure 8). (2) For each chromosome carried by the sperm there is an exactly similar one carried by the egg. Consequently when fertilization takes place (figure 8) (3) that is to say when a sperm penetrates an egg, the resulting fertilized egg will have the double number—two of each kind of rod.

Now our bodies are slowly produced from the fertilized egg by the division of the latter into 2, then 4, then 8 and so on until a mass of cells is produced which gradually takes on the form of our body (figure 2). When the fertilized egg divides every chromosome splits into 2 and these daughter chromosomes move apart, going to opposite ends of the diving cell. The same process occurs in all cell divisions so that every cell in the body will contain the double set of chromosomes.

The cells which produce the reproductive cells therefore have the double set, but before their last division (figure 8) (5) the chromosomes within them mate in pairs. Corresponding chromosomes, i.e., one received from the father and one from the mother unite. Then they pull apart and each member goes into one of the daughter cells. Therefore each mature germ cell receives one or the other of such a pair, but not both. The number of rods in the germ cell is thus one-half that in the ordinary cells—there is only one set. Now in these manoeuvres of the chromosomes we have the whole explanation of the laws of heredity. In our example a factor (L) in one of the chromosomes (square) contributed by the father is responsible for the development of long wings. A factor in the corresponding chromosome contributed by the mother is responsible for the development of vestigial wings (V). The two chromosomes will be found in all the cells of the body of the hybrid, but the long will dominate the vestigial. When the reproductive cells are formed in the hybrid's body the chromosome containing the factor for long (derived from the father) will go into a different germ cell from that containing the factor for vestigial. That is the germ cells are pure for one or like other of the contrasting characters. Thus we see that the laws formulated from the results of actual breeding experiments might have been predicted from an anatomical study of the behaviour of the reproductive cells.

Sex Determination

An important by-product of this anatomical study is the discovery of how sex is determined (figure 9). Every cell of the body of a woman has 48 of the rod-like chromosomes. Every cell of the body of a man has 47 rods. Since the reproductive cells have half the number that the body cells have (as a result of the peculiar division) the female reproductive cells or eggs will have one-half of 48 or 24. The male cells or sperms should have one-half of 47. but since there cannot be one-half chromosome the result is that there are two sets of sperms, one set with 24 and the other with 23. And these two kinds will be produced in equal numbers. Now when any egg is fertilized by a sperm with 24 rods the resulting cell will have 24 and 24, equal to 48 chromosomes, which is the number in the female body cells and the offspring will therefore be a female. If on the other hand any egg is fertilized by a sperm with 23, the resulting number is 24 and 23, equal to 47, and the offspring will be male. And since the two kinds of sperms are produced in equal numbers, it is obvious that in the long run the numbers of the two sexes must be equal. Thus we see that sex does not depend on food, or drink or relative age or vigor of parents, or the condition of the moon, or on any of the hundreds of causes that have been assigned to it, but is really determined by the intrinsic structure of the fusing germ cells and cannot possibly be modified. Not only in human beings but in all animals is sex similarly determined by the constitution of the fusing germ cells.

The two fundamental principles of heredity therefore are the non-inheritance of acquired characters, and Mendel's Law. The first shows us what characters are inherited and the second how they are inherited. We now pass on to consider some of the applications of these principles.

Application in Plant and Animal Breeding

An application of great economic importance with which connection with which every teacher in an agricultural community should be

FIGURE 7

Mendelism in Pigs.

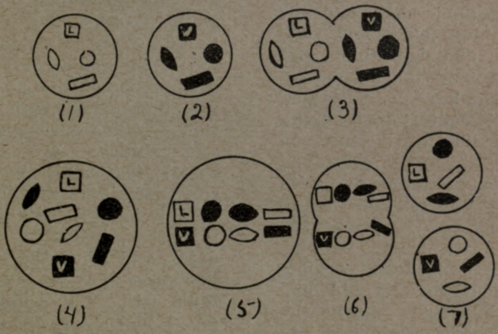

FIGURE 8

Explanation of Mendel's law on basis of an anatomical study of the chromosomes. (1) Sperm or male germ cell; (2) egg or female germ cell; (3) fertilization; (4) any cell of body of offspring; (5) and (6) division which gives rise to germ cells of offspring. Note how the corresponding chromosomes, one derived from the father and one from the mother, mate and then pull apart; (7) germ cells of offspring.

acquainted is in connection with plant and animal breeding. The breeder who knows Mendel's Law need no longer work in the dark. Before the discovery of the law he could only cross and trust to luck or Providence to give him what he wanted. Usually either luck or Providence took away the good qualities he already had. Now he can combine good qualities and eliminate bad ones according to the definite rules just as soon as he determines how his given qualities are inherited. Now he can plan his work and predict just what proportion of any generation will contain the combinations of characters which he desires, and can quickly determine which of them will breed true. For example, most of our good wheats are very susceptible to rust while certain inferior strains are very resistant. Professor Biffen crossed a susceptible strain possessing otherwise desirable qualities, with a resistant strain possessing other undesirable qualities. In the first hybrid generation some desirable characteristics were dominant while some were recessive. But in the second hybrid generation in accord with Mendel's Law there were all combinations. A certain proportion contained only undesirable qualities; most contained various mixtures of desirable and undesirable; a small proportion (previously calculated) contained only desirable characteristics, among which was resistance to rust. In the same way Webber has combined the good qualities of the orange with the hardiness of the wild citrus, so that oranges may now be grown 300 miles further north than ever before, and the southern orange grower is relieved of his old bigbear—damage by frost. Again the large size of the leaf of the Havana tobacco has been combined with the large number of leaves of the Sumatra tobacco, in a new variety the Halliday, which is supplanting its parents from the eastern tobacco fields. Such examples could be multiplied. This type of work would be quite impossible without an understanding of Mendel's law. As the knowledge of heredity spreads into our agricultural colleges and schools the better farmers will be doing this for themselves. Here in the west perhaps more than anywhere else, there is great need for such work.

Human Heredity

Let us now turn to the human applications of the new knowledge of heredity, the applications in the improvement of the physical, mental and moral qualities of the human race. Such applications are very much to be desired at the present time for several reasons. In the first place the need for innate ability is increasing with each generation, while the ability itself is not increasing. Man hands down to his descendants the results of his experience, and training, and progress, through tradition, custom and writing. Thus the store of knowledge increases with every generation. To be successful under the conditions of modern life human beings must know a great deal more than in the past and of each successive generation more is required The intrinsic conditions of life grow more complex with every age. But there is no evidence that human ability is increasing correspondingly. The internal heredity remains unchanged. The boys of the present generation are no stronger mentally than those of the ancient Greeks. Looked at from another point of view this is the reason, I believe, for the existence of those things against which the moralist and religionist are continually complaining. The aspirations, the impulses, the responsibilities of modern life are increasing with every generation, while our inherited natures and abilities are not improving. social (external) heridity has outrun germinal (internal) heredity. There is a continual struggle of primitive instincts against newer deals, and when the former conquers the preacher has somethng to find fault wth. But whether we put it on a moral or on a mental basis there is great need of breeding a race of men with greater hereditary capabilities.

But there are other reasons why human beings should apply the laws of heredity to the improvement of their own race. The human species is the only one in which natural selection is inoperative; man is the only being who protects and cares for his weak and incompetent brothers and allows them to reproduce, spread their defects and thus lower the general standard. Again, we hear a great deal about race suicide. A declining birth rate

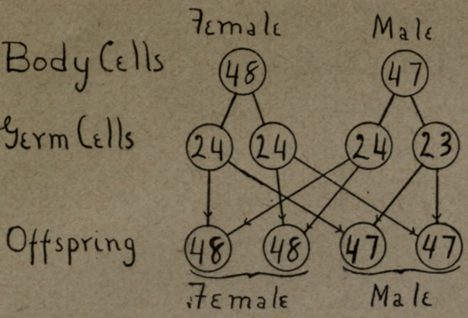

FIGURE 9

Sex determination. See text.

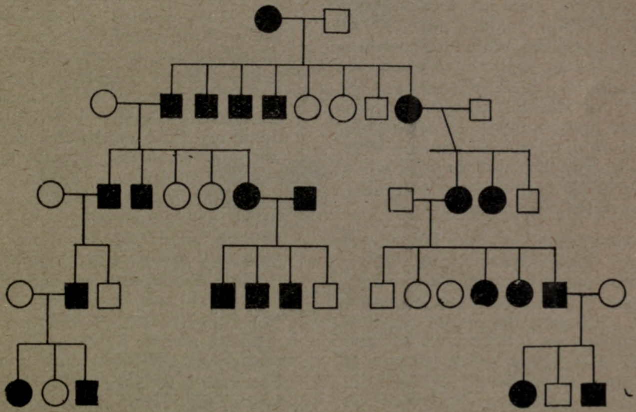

FIGURE 10

Family tree showing inheritance of cataract of the eye. The individuals represented by black symbols were affected, the others normal. Circles indicate women and squares men. Joining of two by a line indicates marriage. This figure shows the defect to be inherited as a dominant.

would probably be a good thing if applied equally to all classes, but when the decline is chiefly among the upper classes the result is distinctly bad. And statistics show us that the whole of the present generation was produced by one-quarter of the last, and that quarter was on the whole the least desirable human class.

Inheritance of Physical Characteristics

As yet only a beginning has been made in the study of human heredity. But already many important facts have been brought to light. In regard to physical characteristics we have learned for example that the different eye colors are inherited as true Mendelism units. Blue eyes are recessive to brown. Therefore, when both parents are blue-eyed all the children must also be blue eyed, for if either parent carried the factor for brown it would dominate the blue and, therefore, reveal itself. When both parents are brown-eyed either all the children are brown or one-quarter are blue, depending on whether the parents carried blue in a recessive condition. When one parent is brown-eyed and the other blue, either all the children will be brown or one-half will be blue, depending on the purity of the brown-eyed parent for brown. Of course a blue-eyed person must always be pure for blue because if the unit for brown were present it would dominate the blue and reveal its presence.

The inheritance of eye color and skin color, though more complicated, follows the same general rule. Two blonde parents do not have brunette children, though brunette parents may have blonde children. The condition in which an extra finger is present and the one in which the fingers are short are inherited as simple dominants. The tendency to produce twins at each birth is a recessive. We have also learned a great deal about the inheritance of disease. Of course no bacterial or contagious disease can possibly be inherited. A predisposition towards a particular disease, such as tuberculosis, may be transmitted, but the disease itself can never be. On the other hand resistance to disease is inherited, a fact which gives the new field for work. Non-bacterial diseases are in a different category. Cataract of the eye for example is inherited as a simple dominant, so that either all or one-half the children will exhibit the defect, depending on whether the parent is pure for the defect (fig. 10). Deaf-mutism is a simple case (fig. 11). Color-blindness is inherited in peculiar fashion because the factor which causes it is located in the same chromosome as the sex factor. Many examples might be given of physical defects as well as normal physical characters whose exact mode of inheritance has recently been determined.

Mental and Moral Qualities

But for all of us the most valuable results have been obtained in connection with the inheritance of mental and moral qualities. It is unnecessary to tell a gathering of teachers that mental capacity is inherited. If they have failed to observe it among their pupils, a consideration of such families as the Oslers and Merediths, of Ontario, or the Lowells, of Boston, would convince anyone. One of the most striking cases is found in the family of the greatest biologist, Charles Darwin (figure 12). All the individuals represented by black symbols attained at least country-wide eminence, chiefly in science. In the same way it can be shown that feeble-mindedness is inherited just as distinctly as is exceptional mentality. Many recorded cases might be cited (figure 13). Goddard, the greatest authority in feeble-mindedness on this continent, states that without quetsion two-thirds of the cases are directly due to heredity, and that while the remaining one-third are apparently due to other causes, such as accident, there is porbably a hereditary basis even for these. The value of the work, however, lies not so much in proving the inheritance of these conditions —many people believed it or at least suspected it before—but in revealing the exact mode of inheritance. We know now that both great mental capacity and feeble-mindedness are inherited as recessives. Two feeble-minded parents can have none but feeble-minded children (fig. 14), but an apparently normal person may be a carrier of feeble mentality in a recessive condition. Herein lies the great difficulty in handling the problem. If two normal carriers of the defect marry they will have a certain proportion of defective children. This appearance of children of different capacities in the same family led many students to doubt the inheritance of mentality, whereas it is really the strongest confirmation of our laws of heredity. It is

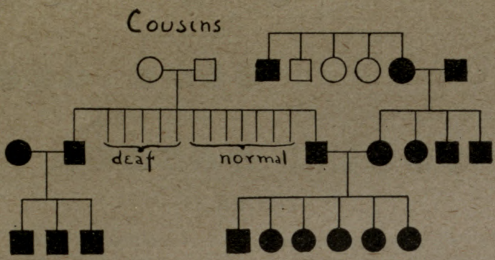

FIGURE 11

Family tree showing the inheritance of deaf mutism. Note that where both parents are deaf mutes, all the children will also be deaf mutes.

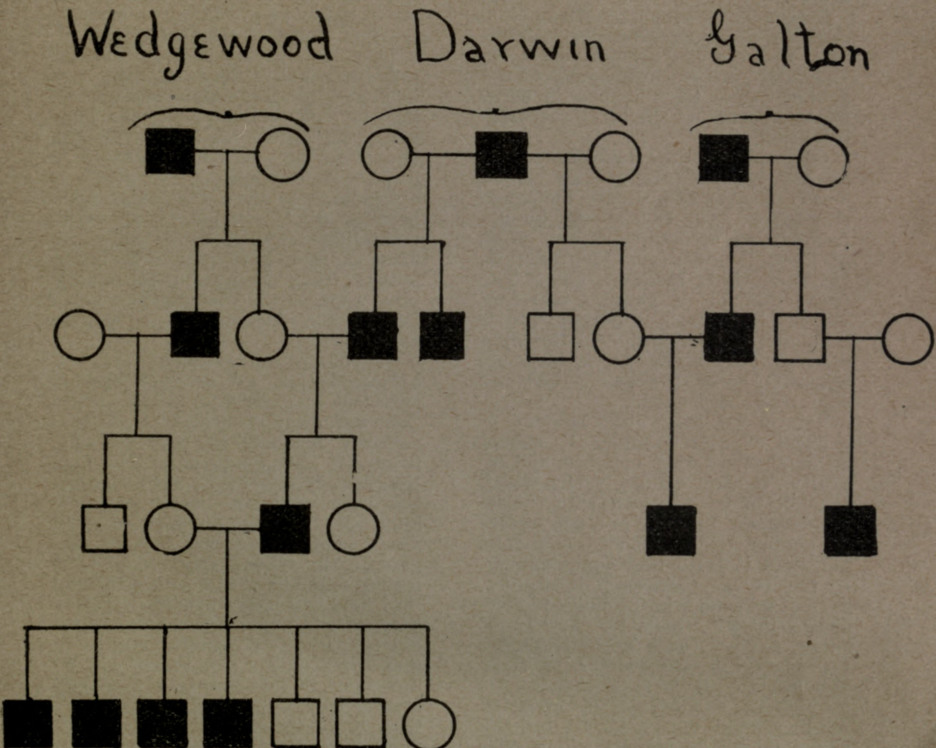

FIGURE 12

Inheritance of great mental ability in the families of Darwin, Galton and Wedgewood. All the individuals represented by black symbols attained at least country wide eminence chiefly in science.

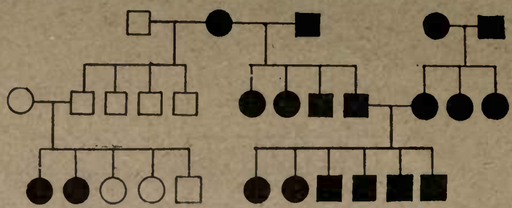

FIGURE 13

Family tree showing inheritance of feeblemindedness. The defective woman at the left of the upper line married twice. One husband was normal and the other feebleminded. Note that where both parents are feebleminded all the offspring are likewise feebleminded, but that two apparently normal people may be carriers of feeblemindedness (lower left).

exactly the same as the appearance of our one recessive vestigial fly out of four in the second hybrid generation.

Strangely enough great mental capacity is also a recessive. Therefore the sturdy normal mass of humanity produce neither defect nor genius unless they happen to carry these characters in the recessive condition.

Of course the inheritance of mental condition is not so simple as in the case of ordinary biological characters. The best mental quality is made up of many factors. Each of these is inherited independently, but each obeys Mendel's Law. The production of a genius, therefore (unless it be from a parent who is a genius) is comparable to throwing dice so that many aces turn up. Scientific heredity shows us how the dice may be loaded.

Before we leave the subject of general mental capacity it should be emphasized that epilepsy and insanity, though definitely inherited, are not to be confused with feeblemindedness. Insanity is much nearer to genius (as the poet truly tells us) than it is to feeble-mindedness. It too is a recessive. Therefore, normal persons whose family history shows insanity may be carriers of defect and two such normals should not marry or one-quarter of their children are likely to go insane. It is doubtful if a normal of defective strain should marry at all for the defect which he carries will simply be spread undiluted even though it may not appear in the next generation.

Not only general mental ability but also special mental traits are inherited in definite fashion. For example musical ability is inherited as a recessive. So is literary and artistic ability. Definite informaton has also been secured in connection with mechanical ability as for example in the family history of the Pomeroys, of Massachusetts.

There is also the best of evidence that criminality and morality are inherited in Mendelian fashion. If that is true criminals may be little more responsible for their acts than one of us for having red hair or a big nose. Furthermore evidence is not lacking to show that such qualities as tact, stubbornness, sentimentality, impulsiveness, wit, selfishness and thriftness are transmitted from generation to generation, apparent inconsistencies being due to the phenomenon of dominance.

Of course the criticism may be advanced that we are not making sufficient allowance for factors other than heredity. For example mental capacity depends in part on temperament and disposition. Two men equally endowed with grey matter, but with different livers, may exhibit very different mental capacity. Again suppose a father is very successful in some special field of mental activity; his son will find that field attractive because of early associations and may, therefore, apply his inherited general ability in that same field. The result will be the apparent inheritance of a special mental trait. In general it is urged that it is inconceivable that such minute characteristics should be transmitted. But we know that exceedingly minute physical differences are certainly transmitted. For example cataract of the eye affects only one-twentieth of the lens or a portion weighing only one-six thousandth of an ounce. A condi-

tion in which a few hairs in the eyebrow are longer than the others, or a minute depression in the skin are definitely inherited. Again everyone knows that different breeds of dogs have hereditary peculiarities of temperament, affection and intelligence. Why may not such hereditary differences be found among human beings?

Let us now take a concrete illustration of the effects of these laws of inheritance on the future of the human race. Elizabeth Tuttle was a New England woman of great beauty and wonderful intellect. In 1667 she married Richard Edwards. After one child was born they were divorced and Richard Edwards married again, this time a woman of average mentality—Mary Talbot. None of the descendants of this second marriage rose above mediocrity. But the descendants of the first marriage—all of whom carried the reproductive plasm of Elizabeth Tuttle, include a wonderful array of eminent men. Timothy Edwards, a pastor of great learning; Jonathan Edwards, one of the world's greatest intellects, pre-eminent as a theologian, president of Princeton University; Jonathan Edwards, Jr., president of Union College; Timothy Dwight, president of Yale; Sereno Dwight, president of Hamilton; Theodore Dwight Woolsey, 25 years president of Yale; Daniel Tyler, a general in the civil war and founder of the iron industries of Alabama; Timothy Dwight 2nd, president o. Yale 1886 to 1898; Theodore Wm. Dwight, founder and head of Columbia Law School; Merril Edward Gates, president of Amherst; Catharine Maria Sedgwick, the authoress; Chas. Sedgwick Minot, the eminent embryologist and biologist of Harvard Medical School; Winston Churchill, the American novelist and politician; Mrs. Theodore Roosevelt, whose mentality is very little below that of her illustrious husband; Aaron Burr, vice-president of United States; Morrison R. Waite, Chief Justice of United States; Ulysses S. Grant and Grover Cleveland, Presidents of United States.

On the other hand take the family of the Jukes. It was founded about 1700 in New York State by a shiftless backwoodsman named Max Juke. The descendants include 1,200 people, of whom 130 were paupers, 450 diseased wrecks, at least one-half the women immoral. Twenty descendants only learned trades, ten of them through compulsion in prison. In mere monetary expense the family has cost the state of New York alone one and one-half million dollars.

These two cases not only show the force of heredity, but they also emphasize the immense effect of the individual for good or evil on future generations. It is impossible to conceive of the immense influence of the long line of college presidents and statesmen on the development of the American people. And they all received a share of the germ plasm of Elizabeth Tuttle. Nor can we estimate the influence for evil of the Jukes. It would be a wonderful thing for our country if the immigration officials could distinguish the Elizabeth Tuttles from the Max Jukes. And all this influence is due directly to Mendelian inheritance by which traits of character are passed on undiluted to immense numbers of descendants.

Heredity Versus Environment

Now it may be asked whether so many of the Edwards became eminent because their heredity was good or because they were born into a good environment. On the other hand are the Jukes all low and sordid because of their heredity or because their environment was miserable? It is the old question of heredity versus environment. To what extent is man the creature of heredity? To what extent the product of education? To what extent may education and training make up for the defects of birth? Everyone admits that environment and training is of great importance—much greater in man than in the animals. But we are just learning how relatively effective is heredity. Those most competent to judge, men like Galton, and Thorndike and Conklin, have come to the conclusion that heredity prevails enormously over environment or as Galton phrased it: "Nature is much more important than nurture." Their most convincing facts are obtained in investigations of the lives of identical twins (whose heredity we know is exactly the same) in widely different environments. They have shown that "the modifications produced by environment and education are small and temporary as compared with those determined by heredity." Thinking men conversant with the facts will never again return to the position which prevailed until recently in regard to the all-importance of environment.

For example the unfit fill our slums not because of lack of training or opportunity but simply because they gravitate there while the fit (through heredity) occupy the better places. The physical and mental degeneration of the slums is not due to excessive drinking, but the drinking to the degeneration.

But it seems to me that too much emphasis is put on the antagonism between heerdity and environment, when they are usually not antagonistic at all but co-operative. Instead of opposing each other they pull together. In cases of insanity, for example, there is usually defective heredity and a special inciting cause such as an accident. Men break down from overwork, but many others work just as hard and never break down. There is commonly a special inciting cause working on a defective basis.

Now all our social, ethical and educational institutions deal only with environment. Our social institutions, with their commands and prohibitions, rewards and punishments, are built on the principle that men are made by environment and training. The foundation stone of democratic society is the belief that "all men are created free and equal." But our studies in heredity show us that all men are by no means equally endowed. There always have been classes and always will be so long as men are differently endowed by heredity. It is doubtful whether our institutions should try to obliterate class distinctions as is at least their professed aim at the present time. Their efforts should rather be bent to rectifying class distinctions and to giving everyone a chance to get into the class to which he belongs through heredity. We teachers in particular must proceed on the basis of the known fact, however unpleasant, that men are created very unequal and that environment and training are not the most important factors in producing a high standard of mankind.

Possibility of Uplift.

These conclusions naturally raise the question whether there is any possibility of permanently uplifting the inborn qualities of humanity through educational, sociological and religious work. Everyone is proud of the progress in external inheritance. Man stores knowledge like a bee stores honey, and passes it on to his children. Progress means that the hoard is enlarged or improved. But this does not effect the internal (germinal) heredity. Every generation must begin at the beginning, not at the position to which their fathers had attained. Better food, better housing, better hygiene, will help to make full use of inherited qualities, but will not change those qualities. This is true because of the great biological principle that acquired characters are not inherited. If mathematical ability is present in the germ cells. education will make the most of it, but if it is absent no amount of education can make a mathematical genius. The germ cells know nothing of the calculus. A man's sons are of no greater mental capacity because their father was educated. "The saving grace is with the germ cells; the future of the race is wrapped up in the recognition that we give them." Criminality or pauperism can never be eliminated by measures for their amelioration, but only by measures which deal with heredity, that is to say, eugenical measures. This does not mean that we should give up our efforts to improve the environment and training. On the contrary it means that we should direct our energies a the more strenuously to the business of re-impressing on each generation the desirable modifications. "Although what is acquired may not be inherited, what is not inherited may be acquired."

Heredity and Ethics.

One other general inference from our work in heredity must be referred to—its bearing on our ethics. It is plain that heredity determines most of our actions. The main characteristics of every living thing —the species, family, and personal traits—are unalterably fixed by heredity. Psychological, physiological, moral possibilities are predetermined in the germ cells—for who by taking thought can add one chromosome to his organization. This has led some students in heredity to take the position that all our actions are pre-determined and that we act merely as machines. If personality is determined by heredity alone all teaching and preaching are useless; freedom and responsibility are delusions. Therefore we shouldn't punish or admonish children; they do only what their inherited natures make them do. "Lying and stealing will cure themselves like the measles or will be incurable. Laziness is due to inheritance or hookworm; the latter

can be cured but not the former. Villains, law breakers, murderers are to be pitied, not punished." The law breaker may be answerable to society, but he is not responsible in the sense of deserving pain because of the defects of his heredity. I am what the factors in my germ plasm developed into in an environment over which I had almost no control. But this view is much too extreme. While the main characteristics of our minds and bodies are undoubtedly inherited, not all the possibilities are fixed. A great deal can be done by early training and exercise of the will. The will is not absolutely bound. Men are to a limited extent responsible for their actions. Our actual personalities are not pre-determined in our germ cells even though our possible personalities may be. Nevertheless it is plain that we cannot return to the old position that all our actions rest on voluntary choice and for such choice we are to be held responsible. The truth lies between the two extremes. Criminals are often not all responsible for what they do, and are no more deserving of punishment than we for being sick. The deliquent and criminal are too often subjects for treatment by the doctor and student of heredity rather than by the jurist. When all the factors, hereditary and otherwise, are properly balanced the incorrigible sinner probably often deserves greater credit for the life he has led than our spotless first citizens.

Summary.

Let us finally sum up the points in which our recent advances in heredity have a bearing on educational policy:—

(1) Our teachers of biology should familiarize themselves with the new ideas so that they may teach them in their regular classes. No Scientific subject is more fundamental and none has more important points of contact with human life.

(2) In a province in which agriculture is by all odds the most important profession all children should be carefully taught these basic principles which are used and which they may use in the improvement of their crops and animals.

(3) We should more clearly recognize that different children and men are very differently endowed as to mental capacity. The methods and aims adopted for one child may totally fail with another. "The essence of all education is self discovery and self control. When education helps an individual to discover his own powers and get the most out of his heredity it will fulfill its real function." Information is not the most important thing in education. Children are to be taught not merely to know things, but to know themselves; not merely how to do things, but how to compel themselves to do things.

(4) We must similarly recognize that different children and men are differently endowed as to moral natures, that their actions are very largely determined by their hereditary personalities. I believe this will modify the teacher's methods. It should certainly modify his attitudes and sympathies.

(5) We teachers must frankly admit, however disappointing it may be, that our labors can have no effect in improving the inborn qualities of mankind. It does no follow that we should slacken our efforts to improve the external inheritance, but rather increase them. It is something to get rid of false hopes, to learn our limitations. We shall then search the more vigorously for the true methods of improving the qualities and apply the true methods the more rigorously.

(6) The proper methods of improving the human race are the methods of eugenics—the prevention of the reproduction of the unfit, the encouragement of greater reproduction by the fit, the exclusion of unfit immigrants, the taking of a eugenic survey of every family in the country, and above all the spreading of the knowledge of heredity through our ordinary educational channels. Education of the mass of the people in the facts and laws of heredity is more to be desired than any legislation. When these measures are applied the sociological improvement will come as a by-product of eugenic improvement, for the eugenist deals with real causes while the social worker deals with symptoms.

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